R E P O R T   R E S U M E S

ED 016 533 PS 000 383

TRAINING EFFECTS AND CONCEPT DEVELOPMENT--A STUDY OF THE CONSERVATION OF CONTINUOUS QUANTITY IN CHILDREN.

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PUB DATE 68

EDRS PRICE MF-$0.25 HC-$0.52 11P.

DESCRIPTORS- *TRANSFER OF TRAINING, *CONCEPT FORMATION, *MATHEMATICAL CONCEPTS, *COGNITIVE MEASUREMENT, COGNITIVE DEVELOPMENT, PRETESTING, POST TESTING, RETENTION, MENTAL DEVELOPMENT, LEARNING PLATEAUS, TRAINING TECHNIQUES, *EARLY CHILDHOOD, PIAGET

A STUDY WAS CONDUCTED TO FIND OUT WHAT MENTAL PROCESSES ARE INVOLVED IN THE DEVELOPMENT OF THE CONCEPT OF CONSERVATION OF CONTINUOUS QUANTITY, AT WHAT AGES THESE PROCESSES ARE DEVELOPED IN CHILDREN, AND WHETHER THEY ARE ADEQUATELY EXPLAINED BY PIAGET'S THEORY. ONE HUNDRED 5.75 TO 7-YEAR-OLDS WITH A MEAN I.Q. OF 105 WERE PRETESTED AND CLASSIFIED AS CONSERVERS, NON-CONSERVERS, OR PARTIAL CONSERVERS. HALF OF THE NON-CONSERVERS AND HALF OF THE PARTIAL CONSERVERS WERE GIVEN 1 15-MINUTE TRAINING SESSION (USING CONTAINERS OF LIQUID) BASED ON THE THEORY THAT THE MENTAL PROCESSES NEEDED FOR CONSERVATION WERE (1) RECOGNITION OF IDENTITY (QUALITY OF QUANTITY REMAINS UNCHANGED EVEN IF TRANSFORMED, (2) A LOGICAL MULTIPLICATIVE OPERATION (ALTERATION IN HEIGHT OR WIDTH MIGHT BE COMPENSATED FOR BY THE OTHER), AND (3) OPERATIONAL REVERSIBILITY (QUANTITIES ARE UNCHANGED IN RECIPROCAL OPERATION). A MATCHED CONTROL GROUP HAD NO TRAINING. POSTTEST I (THE PRETEST) RESULTS SHOWED THAT ALL BUT 4 OF THE CHILDREN TRAINED WERE RECLASSIFIED AS CONSERVERS. A DIFFERENT POSTTEST GIVEN TO ALL 100 SUBJECTS SHOWED THAT CONSERVER LEARNING WAS RETAINED AND TRANSFERRED, SUGGESTING THAT 1 OR ALL OF THE SUGGESTED MENTAL PROCESSES MUST BE NEEDED AS PIAGET'S THEORY CLAIMS. HOWEVER, THEY MAY EXIST IN CHILDREN AT AGES EARLIER THAN PIAGET PREDICTED. (MS)

TRAINING EFFECTS AND CONCEPT DEVELOPMENT: A STUDY OF THE CONSERVATION OF CONTINUOUS QUANTITY IN CHILDREN

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INTRODUCTION

Piaget and his colleagues have conducted a number of investigations which have indicated that children below the ages of approximately seven or eight do not understand that the amount of a substance remains invariant despite transformations in shape or arrangement. This concept has been termed the concept of conservation and when applied to fluid quantities which are not readily discernable as separate entities, it is termed the concept of continuous quantities. A child who has not developed this concept usually thinks that when a quantity of fluid is poured from one container into another which is taller and narrower, the quantity of the fluid increases with the rise of the level of the fluid.

Many studies concerning children's conservation concepts have been conducted by investigators who have focused on identifying the ages and stages of conceptual development. However, more recently, studies have centered on attempts to determine the effects of training or experience on the acquisition of the concept. Relatively few of the latter have achieved conclusive results and have been criticised on at least two counts. It has been suggested that the lack of success may be attributable to the fact that either the investigators did not employ sufficiently long periods of training, or that they did not ascertain with sufficient accuracy the necessary procedures which would lead the child to an understanding of the concept.

The purpose of this study was to investigate the acquisition of the concept of conservation of continuous quantity and to attempt to develop the concept experimentally. In addition, the answers to three specific questions were also sought. (1) What mental processes are involved in the development of the concept of conservation of continuous quantity? (2) Can these processes be satisfactorily explained by Piaget's theory? (3) Can these processes be developed in children earlier than is normally the case according to Piaget?

Assuming that previous studies had failed to isolate the specific cognitive abilities children need in order to understand conservation, this study was based on the hypothesis that conservation would result when children who had been classified as non-conservers were provided with experiences designed to lead them to an understanding of the conservation principle. These experiences were hypothesized to be those which would help the children develop the understanding that a fluid retains its identity during transformations, an understanding of the compensatory relationship between height and width, and a knowledge of the principle of reversibility.

In general, the research hypotheses stated that there would be significant changes in the numbers of non and partial conservers after training, that the experimental subjects would be able to retain the concept over a two to three week interval and that there would be no change in the control group.

The population from which the sample was drawn consisted of the total enrollments of two elementary schools in Edmonton, Alberta, Canada. The stratified random sample involved in the study was comprised of 120 subjects of whom 20 took part in the pilot study only. The mean chronological age of the total sample was 6.15 and the mean intelligence quotient was 104.46. The range of the chronological ages was from 5.75 to 7.00. The stratification criteria were:

1. Intellegence. Subjects whose scores on the Detroit Beginners Test (normalized for Edmonton) did not fall within the range of 95 to 115 were excluded from the study.

2. English as the native language. Subjects who came from homes where English was not the native language were also excluded.

3. Defective vision. Children whose school records indicated uncorrected visual defects were not included in the study.

The Pretest and Classification of Subjects

The pretest consisted of four sections and was administered to each subject individually. The first two sections were derived from Piaget's classical test of conservation of continuous quantity, however, more responses were elicited from the subjects than in Piaget's original test.

In section one, the subject was confronted with two identical beakers, equally full of colored water. A tall narrow graduate was placed on the table and the subject was asked if the quantity would be the same if one of the beakers was poured into the graduate and how he could tell this. At this point the examiner poured the fluid and asked if the quantities were equal. If the subject said they were unequal, he was asked how they differed and whether they were "really" different or merely looked that way. Again he was asked how he could tell. While the beakers and graduate were still in front of the subject, he was asked what the two beakers would look like if the contents of the graduate were poured back into the original beaker, and again, how he could tell.

A similar procedure was used in the second section of the pretest with the exception that a flat, shallow dish replaced the graduate.

The "How can you tell?" questions were included in an attempt to find out what attributes the subjects were centering on in forming their decisions. The question asking whether the containers were "really" different or merely looked that way was included since it was felt that a subject might understand the conservation principle, but when asked to compare the two sizes of containers he might center on the water levels and give a "non-conservation" response. This, in fact frequently occured. The final question regarding the appearance of the beakers if the contents of the graduate were returned to the original beaker was added in order to shed more light on the problem of reversibility. With regard to the latter, it should be noted that true reversibility in this study was defined as involving two related aspects: Inversion, in which the subject mentally performs a reverse operation (pouring the water back into the original beaker) and reciprocity, in which one operation may compensate for another, in this case the understanding that increased height is compensated for by a decrease in width.

The third section of the pretest attempted to ascertain the subject's understanding concerning the sameness or identity of the fluid after it was poured into another container. Bruner has stressed the importance of this factor and claims that it is a prerequisite to an understanding of the conservation principle. In this study, the subject was confronted with two identical beakers, one of which was half full of colored water. The subject was invited to consider the fluid as his own special drink and a name was given to it, e.g., "orange juice". He was then asked if the fluid would still be "orange juice" if it was poured into the empty container and how he could tell.

The last section of the pretest was comprised of a series of 8 diagrams showing sets of containers. Each set showed at least two containers, one of them partially filled with a colored fluid while the others, were empty. These diagrams were used in an attempt to measure the subject's ability to respond to a conservation problem in what Bruner has termed ikonic and symbolic modes of thought. The questioning technique involved asking the subject if the fluid would alter in quantity if poured from the one container into one/or more of the others shown.

On the basis of the results of the pretest, the subjects were classified into non-conservers (N = 59), partial conservers (N = 21) and conservers (N - 20). A non-conserver was defined as a subject who failed to conserve in both sections one and two of the pretest and a partial conserver was defined as a subject who gave conservation responses in one but not both of the first two sections. The non-conservers and partial conservers were randomly assigned to experimental and control groups resulting in 29 non-conservers and 11 partial conservers in the experimental group while the control group consisted of 30 non-conservers and 10 partial conservers.

The Training Procedures

For the purposes of the training sessions, the experimental group was divided into four groups of ten subjects, with partial and non-conservers in each group. Every group met with the experimenter for one 15 minute training session.

These sessions were designed to accomplish several purposes simultaneously. These were: (1) to help the S's realize that pouring a liquid does not alter its quality, that is, that the liquid retains its identity over transformations; (2) to shield the S's from their initial perceptions of the situation and at the same time help them to understand that pouring does not alter the quality of the fluid; (3) to confront the S's with the changes in the height of the water levels after the fluid had been poured and to help them understand and verbalize the compensatory relationships between height and width as applied to the containers. Once this aspect of the training had been completed, the S's were given practice in applying their learning to pictorial representations of similar situations.

While the exact wording of the sessions varied slightly depending upon the responses of the S's, the general procedure was as follows. In section one dealing with the identity relationship, the group was seated around a large table while the E poured drinks of "juice" from a large container into a variety of tin cans. The group discussed whether pouring would effect the kind of drink being poured. Responses were elicited from the S's and where an incorrect answer was given, the E asked if anyone had a different answer. At no time did he comment on the correctness of any response. Regardless of the correctness of the response, the S was asked to explain how he had figured out his answer.

The second section of the session dealt with the understanding that the quantity does not change with transformations. Again, tin cans were used but the S's were told that they were going to be talking about how much there was to drink. E poured a "drink" into a tin and then suggested that since that tin was dirty, the "drink" ought to be poured into another similar tin. The group was then asked whether pouring the "drink" would change how much there was to drink. Answers and explanations were elicited then E repeated the procedure, this time pouring the "drink" into a tin of a different size and shape. This procedure was followed with various sized and shapes of containers and with pairs of subjects coming forward and helping with the pouring and selection of tins. During this time, the water level of the "drinks" was hidden due to the nature of the containers.

The third section of the session was designed to confront the S's with the difference between the height of the water levels after the drinks had been poured. In this case, new containers were introduced. These were pieces of glassware of various shapes and sizes each of which had been completely covered with paint except for a narrow vertical strip on the back. The function of the paint being to prevent the S's from seeing the level of the liquid until E turned the container around at which time the level could be viewed through the unpainted strip.

After pouring the "drinks" back and forth between various containers and discussing the effects on quantity, the S's were asked to predict where they thought the level of the drink would be in each container. Individuals were invited to come forward and point out their predictions with their fingers after which E turned the container to the clear strip and the S's predictions were checked out. Again, explanations were elicited from the group members.

The final section of the training session concerned the S's abilities to relate what had been discussed to pictorial representations of containers. This was accomplished by presenting the group with a series of six drawings of sets of containers and asking questions concerning the effects of transferring the liquid shown in one container into another container. Answers and explanations were again elicited from the S's.

Posttest I

The first posttest was administered to every subject in both the experimental and control groups. In the case of the experimental group, the test was given individually to the subject immediately after the completion of the training session. Subjects in the control group received the test after a length of time equivalent to that which would have transpired had they taken part in the training session.

The test itself was identical in every respect to the pretest, was scored in a similar fashion and each subject was reclassified as to his or her apparent knowledge of the conservation concept.

Posttest II

The second posttest was administered to every experimental subject and those subjects who had previously been classified as conservers. This test, which was also administered individually, was given to the experimental group two to three weeks after the training session and to the conservers after an interval of time equal to that which would have transpired had they taken part in the training session and the first posttest.

The test consisted of five sections involving sets of glass containers of various sizes and shapes and was designed to measure not only how well the S retained the concept he had acquired, but also whether he could transfer this knowledge to a new situation using different materials. Accordingly, split peas and lentils were substituted for the colored water in the previous sections. In addition, the containers in this test were extremely unusual in shape.

The questioning techniques followed a pattern similar to that described for the pretest in which the S predicted whether or not the quantity would be conserved, watched while it was poured, answered a question regarding conservation, and predicted what the quantity would look like it it was returned to the original container. Responses were judged correct only if the S could explain why conservation occured. In the first section, a question was added to the usual procedure in an attempt to extinguish the S's conservation response.

The Statistical Analyses

Each of the eight hypotheses was tested by means of an application of McNemar's Test of Significance of Change with an incorporation of Yates correction for continuity.

Results

The results of the study may be summarized as follows:

1. On the basis of the pretest, the sample was classified into three categories: non-conservers (N - 59), partial conservers (N = 21) and conservers (N = 20).

2. Subjects who failed to conserve usually explained their responses by referring to either the height of the level of the water or to the size or number of the containers. Subjects who were classified as conservers were usually able to explain that a difference in the size of containers and the resultant change in the height of the water level did not effect the quantity.

3. On the basis of the results of the first posttest administered after the training situation, twenty-five of the twenty-nine experimental non-conservers were reclassified as conservers and all eleven of the experimental partial conservers were similarly reclassified as conservers.

4. The results of the second posttest indicated that (with the exception of one subject who did not score on section one) all of the experimental non-conservers retained the learning they had acquired and transferred it to a new situation. Each of the eleven partial conservers in the experimental group

achieved similar results.

5. A significant number of non-conservers acquired the concept of conservation of continuous quantity as a result of the treatment.

6. A significant number of partial conservers acquired a better knowledge of the concept of conservation of continuous quantity due to the treatment.

7. An insignificant number of non-conservers changed to partial conservers as a result of the treatment.

8. An insignificant number of non-conservers in the control group acquired an understanding of the concept without benefit of training.

9. The number of partial conservers in the control group who acquired a better understanding of the concept without benefit of training was not found to be significant.

10. No significant change took place in the number of subjects originally classed as conservers over the period that the study was in progress.

11. The twenty subjects classed as conservers at the beginning of the study were all able to transfer their understanding of the concept to a new situation as provided in the second posttest.

12. All of the non-conservers who had taken part in the training sessions were able to transfer what they had learned to a new situation two or three weeks later.

13. All of the partial conservers who had taken part in the training sessions were also able to transfer their imporved understanding of the concept of conservation of continuous quantity to a new situation two to three weeks later.

Discussion of the Findings

Initially, three questions were identified which, it was hoped, could be answered with the data resulting from this study. These questions were: (1) What mental processes are involved in the development of the concept of conservation of continuous quantity? (2) Can these processes be satisfactorily explained by Piaget's theory? (3) Can these processes be developed in children earlier than is normally the case according to Piaget?

The results of the study provide support for the following answers to these questions. The training procedures were based on the theory that the mental processes involved in the acquisition of the concept were an identity operation by which the child would recognize that the quality of the quantity remained unchanged irrespective of the transformations, a logical multiplicative operation in which the child would be able to combine the relationships of height and width and understand how an alteration in one might be compensated for by an appropriate change in the other, and lastly, operational reversibility by which the child would realize that a return to the starting point would find the quantities unchanged and at the same time the understanding that the effects of an operation may be compensated for by a reciprocal operation.

In addition to these cognitive operations, the training also included three procedural techniques; perceptual screening in which the subject's initial perceptions of the problem were hidden from him, a high degree of verbalization by the subject, and the blending of both of the above into a discovery method of teaching.

Since the training was highly successful, it is reasonable to assume that it must have included the necessary procedures and processes required for the development of the conservation concept. Hence, it was concluded that for this sample at least, the theory was proved to be valid. However, it was not possible to ascertain whether all three of the mental processes were crucial to the development of the concept or whether one or two of them may have been sufficient to achieve the desired results.

The second question related to how well Piaget's theory could be used to account for the above mentioned mental processes. An examination of Piaget's works reveals that he has mentioned each of these processes in some connection with the development of the concept of conservation. Piaget refers specifically to the need for an understanding of the identity element during the stage of concrete operations, and with regard to the multiplication of relations, he claims that it is not until the child reaches the level of concrete operations that he can logically combine two aspects of a problem together simultaneously. He has further claimed that this ability is necessary for the understanding of conservation.

Operational reversibility is also cited in Piaget's writings as a characteristic of conservation. Flavell (1963, p. 181) explains Piaget's meaning of reversibility as it applies to concrete thought (which according to Piaget, is when conservation occurs) as follows:

> Thus, the inverse or reversibility property of concrete operational structures assumes two different forms: negation in the case of classes and reciprocity in the case of relations.

This definition appears to agree with the theory propounded by McLaughlin (1963) that reversibility involves inversion and reciprocity.

In summary, it may be stated that Piaget's theory was found to be quite adequate in accounting for the processes upon which the training situations were based. Piaget was found to have dealt with each of the aspects in relation to the development of the concept of conservation in general, and mentioned each of the processes in connection with the stage of concrete operations, the stage at which he claims conservation occurs.

The third question related to whether or not these processes can be developed in children earlier than is normally the case according to Piaget. Piaget argues that a child cannot conserve until he has reached a certain level of cognitive maturity and that the appearance of the ability to conserve is an indication that the child has attained this level. In addition, he claims that the development of requisite mental abilities is dependent primarily upon equilibration and to some lesser degree on maturation, experience and social transmission.

Assuming that Piaget's classical test for the conservation of continuous quantity is both valid and reliable, then subjects who fail to show any indication of a knowledge of conservation as measured by this test, cannot, according to Piaget, possess the necessary cognitive abilities. Conversely, subjects who are able to conserve, as measured by the test, must possess these abilities. How, then, can one explain the reasons for the sudden acquisition of the concept by subjects who previously showed little or no understanding of it?

Two alternative explanations are suggested for the effect of the training procedures. (1) The experimental subjects did not possess the requisite abilities and these were developed during the training session. (2) The subjects already possessed the requisite abilities but were unskilled in their use and the training procedures taught them how to use the abilities. The first explanation does not seem to be tenable for a number of reasons. In the first place, existing research has indicated that is is extremely difficult to develop cognitive abilities in children if certain (as yet undefined) underlying cognitive processes are not already present. Secondly, the training procedures were designed to help the children use certain abilities which were implicitly assumed to be already in existence. Lastly, it is doubtful if anything as complex as a cognitive process could be developed in the short fifteen minute period of the training session. In summary, it is highly improbable that the first suggested explanation could be correct.

This leaves the second explanation to be considered. Support for its case may be found in Piaget's theory as he states that conservation is dependent upon the existence of certain cognitive abilities. Since the subjects acquired the concept, it follows that they already possessed the necessary abilities. In addition, the training procedures were essentially illustrative experiences and depended for their success upon the prior existence of the necessary cognitive structures in the subjects so that the latter could benefit from the training.

In conclusion, it would seem that the second explanation is the most appropriate in view of the results of the study. Such a conclusion has important ramifications in terms of Piaget's claims concerning the ages at which conservation occurs and the existence of the necessary cognitive abilities. In the face of a lack of evidence to the contrary, it is assumed that his sequence of stages for the development of the concept of conservation is correct. However, the results of this study offer evidence that the ages at which these stages occur are incorrect, and that the necessary cognitive abilities are present in children of approximately six to seven years of age but are latent.